MUSHROOMS AND MOLDS: HABITS AND HABITATS[1]

C. WAYNE ELLETT[2]

Department of Plant Pathology, Ohio State University, Columbus, OH 43210

Cooke, in an article in the Ohio Journal of Science in 1973, describes the fungi as "eukaryotic, nonchlorophyllous, reducer organisms which occupy specific niches in all environments." He goes on to say, "they are integral parts of any ecosystem, natural or artificial, which may be delimited."

We do not have a catalogue of Ohio fungi so no one knows how many species actually occur in Ohio, but I have estimated that there are 5000 to 6000 species or about twice the number of seed plants (Ellett 1957). It is interesting to note that Cooke (1973a) records some 138 species of fungi collected in his own backyard, a lot 50 x 142 feet. This number, he admits, could be increased considerably through routine soil sampling and other studies. Reports of soil fungi in Ohio by Huang and Schmitt (1975) and by Williams and Schmitthenner (1965) and their students, support this contention. In 1955, I compiled a list of nearly 1000 species of plant parasitic fungi in Ohio (Ellett 1957) and during the last 20 years, have collected and identified dozens of previously unreported species.

For more than 30 years, I have collected, studied and read about fungi and find them fascinating organisms existing in an amazing variety of form and habitat. The fungi have exerted a profound effect on the life of man. They have been the objects of wonder and speculation from the time of earliest record. Pliny in the first century A.D. wrote, "Among the most wonderful of all things is the fact that anything can spring up and live without a root." It is not my intent to report details of research investigations, but to indicate a few of the various roles of fungi in our environment.

The microscopic fungus, *Phytophthora infestans*, parasitizes potato plants and sporulates on the underside of potato leaflets (fig. 1). This mold devastated the potato crop in Ireland and elsewhere in Europe 125 years ago and caused the Irish famine. Montagne, Berkeley, Lindley, and others studied this fungus and argued about whether it was the cause or the result of the potato blight, while Sir Robert Peel, in a speech in the House of Commons in London, used the famine in Ireland as an excuse for advocating repeal of the Corn Laws which prohibited the import of cheap grain (Large 1940). Thus, a microscopic mold was responsible, at least in part, for establishing the British policy of free trade—a happening which some have said was the most significant in the entire history of Britain.

Rye and numerous other grass species serve as a habitat for the fungus *Claviceps purpurea*, where it produces the ergot sclerotia (fig. 2). Much has been written about the gangrenous and convulsive ergotism that occurs in man and animals after eating ergoty grain or products made from it. Ergotism was an especially serious problem in Europe from the earliest times and even into the 20th Century. This fungus had its impact on history when an oubtreak of ergotism in the cavalry of Peter the Great in 1722 prevented him from undertaking a campaign against Turkey because 20,000 Russian soldiers were reported to have died from

[1]Manuscript received May 11, 1977 and in revised form June 27, 1977 (#77-39).

[2]PRESIDENTIAL ADDRESS—Presented at the 86th Annual Meeting of the Ohio Academy of Science held at Capital University, Columbus, OH, April 23, 1977. Dr. C. Wayne Ellett, retiring president of the Ohio Academy of Science, is a Professor of Plant Pathology and Director of the Plant Disease Clinic at The Ohio State University. He is a specialist in ornamental plant, cereal, and forage crop diseases. Wayne Ellett received his B.S. from Kent State University in 1938 and his M.S. and Ph.D. degrees from Ohio State University in 1940 and 1955, respectively. Dr. Ellett's writings have appeared in many scientific and professional journals and he is widely known as a speaker on *mushrooms* spp. He is a fellow, past president, and past treasurer of the Ohio Academy of Science as well as a member of the Mycological Society of America, the American Phytopathological Society, the North American Mycological Association and Sigma Xi.

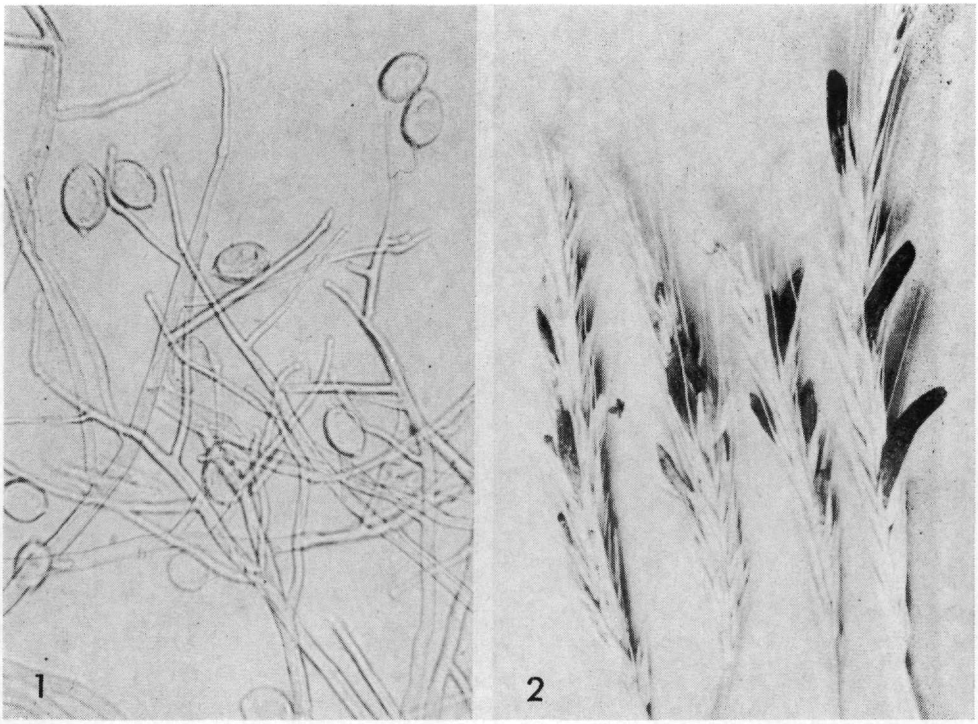


FIGURE 1. *Phytophthora infestans*, a microscopic fungus that parasitizes potatoes causing late blight.
FIGURE 2. Sclerotia of the ergot fungus *Claviceps purpurea* growing on rye inflorescences.

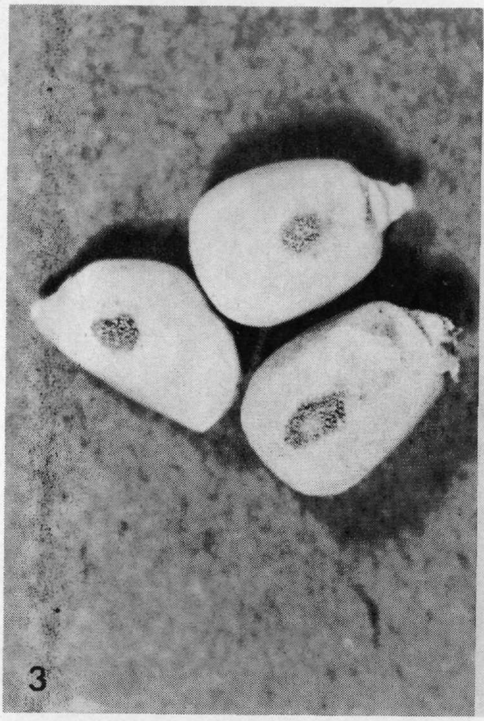
the disease. Caporeal (1976) attempted to relate the occurrence of the Salem witchcraft trials of the 1690's to the ergot fungus—suggesting those accused were suffering from convulsive ergotism. One of the alkaloids produced by the ergot fungus is ergotamine; upon which migraine sufferers around the world depend for relief. Although rare in humans, ergotism in animals still occurs today due to grazing on diseased pasture grasses. I have identified ergot in Ohio on 19 grass species—some of which are first reports for the United States. *Agropyron repens* (quack grass) is probably the commonest host grass in Ohio for ergot. Few have seen the spore-producing stage of the ergot fungus because it is so small and arises from sclerotia buried in the soil.

Downy mildew, a fungus on grapes, was our gift to the French in the 1870's. The resulting disease provided the groundwork for Professor Millardet's development of Bordeaux Mixture [$CuSO_4 + Ca(OH)_2$]; a fungicide still widely used. The threat of downy mildew to the French wine industry was so great that other Mediterranean countries made extensive plantings of grapes, anticipating a wine market for the thirsty French. Millardet's Bordeaux mixture solved the downy mildew problem and grape overproduction in these countries caused an economic crisis (Alexopoulos 1962).

Moving to modern times, in the early 1970's the fungus *Bipolaris maydis* reduced corn yields in the USA by 10–15% or 700 million bushels. This would be worth $1 billion or when fed to cattle would have produced nearly 8 billion one-pound steaks. Many metropolitan newspapers wrote about corn for the first time and informed their readers on the front page about *Zea mays* and *Helminthosporium maydis* (as the fungus was then called). This resulted in the greatest financial loss due to a plant disease in the history of U.S. agriculture. It was the first example of a cytoplasmic factor being primarily responsible for conditioning susceptibility to a pathogen which resulted in a major plant disease.

Fusarium roseum is a fungus that causes an ear and kernel rot of corn. Under some conditions as it grows in corn zearalenone, a hormone-like substance, is produced which causes the estrogenic syndrome in swine. The same fungus, under other conditions, may produce one or more trichothecenes. One of these, vomitoxin, functions as an emetic and/or refusal toxin. Hogs will starve rather than eat corn, if this mycotoxin is present. There are many other examples in an area of research known as mycotoxicology and the extent of mycotoxin contamination of food and feed has only been realized in recent years. *Aspergillus flavus* is a very common fungus and grows in a variety of habitats (fig. 3). Under certain conditions and on some substrates such as peanuts, cotton and copra, a group of toxic metabolites referred to as aflatoxins are synthesized. Fortunately, our major feed grains and soybeans are low risk crops for this synthesis. The story of events leading to the discovery of the aflatoxins as the cause of death of 100,000 turkeys in England in the early 1960's reads like a detective novel. Aflatoxin B_1 was reported to be the most carcinogenic naturally-occurring substance known. The LD_{50} to various animals ranges from 0.3 mg/kg body weight for ducklings to 9.0 mg/kg for mice. In addition to being a carcinogen aflatoxin B_1 is also a teratogen and a mutagen (Ciegler 1975).

For a number of years I have observed and briefly investigated a disease of the adderstongue fern, *Ophioglossum vulgatum*, caused by *Curvularia crepini* (fig. 4). The disease and fungus were first collected in Belgium in 1859 and the only report from the Western Hemisphere is from Columbus, Ohio, where it has been regularly identified during the past 20 years (Ellett 1956). From examination of herbarium specimens of *Ophioglossum* it is evident that Curvularia blight was present in Ohio as early as



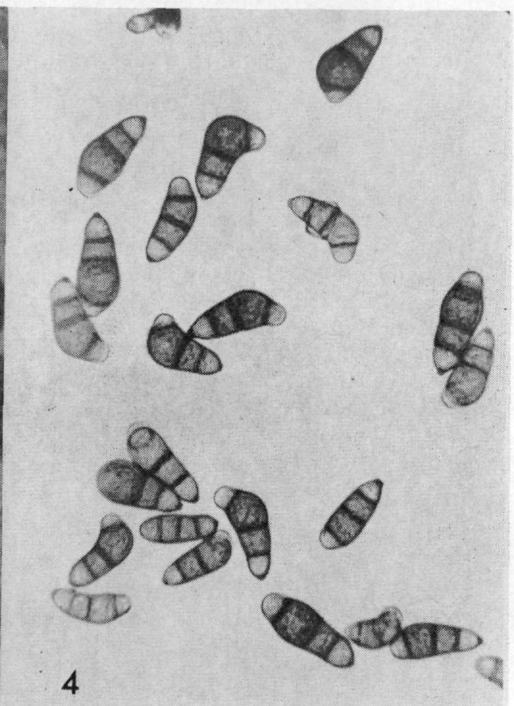


FIGURE 3. *Aspergillus flavus* growing on corn grains.
FIGURE 4. *Curvularia crepini* conidia of the blight that causes Curvularia blight of the adderstongue fern.

1901 and this fungus may be much more common than reports indicate.

Another interesting host-fungus association is the systemic rust fungus, *Chrysomyxa pirolata* on *Pyrola elliptica.* It is a heteroecious rust fungus with species of *Picea* (spruce) as alternate hosts. There are no reports on record of the fungus on our present-day introduced spruces in Ohio. Since *Pyrola* is the host of the repeating stage of the rust fungus, it can persist in the absence of the spruce hosts. One may speculate this rust became established on *Pyrola* during the most recent glacial and immediate post-glacial times when *Picea* species probably were numerous in central and southern Ohio, and persisting since on the *Pyrola* host via the uredinial phase, which is the repeating stage in the life cycle.

Although many individuals have seen the corn smut fungus (*Ustilago maydis*), few have seen the smut fungus that occurs on fire pink, a species of *Silene.* This smut fungus, *Ustilago violacea*, parasitizes several members of the Caryophyllaceae causing anther smut. It is detected on *Silene* by examining the anthers and finding smut spores instead of pollen. The only reports or collections of the fungus in Ohio are those I have made, but few of the 10 million plus Ohioans have spent much time squeezing the anthers of *Silene* stamens.

There were several instances where rust fungi have provided valuable information to plant taxonomists. According to Holm (1969), the true affinities of the grass genera, *Molinia* and *Spartina* have been clarified by studying the rusts parasitic on them. It has been observed repeatedly that a rust fungus regularly differentiates between two species of *Dicentra. Cerotelium dicentrae* occurs on Dutchman's breeches but not on squirrel corn, even though the leaves of the two species are morphologically indistinguishable. This rust has been collected over a period of years in Ohio in an area where both *Dicentra* species are common, and I find it only on Dutchman's breeches (fig. 5).

Insects and fungi are associated in a number of ways. One such relationship resulted in the gradual elimination of the American elm in the United States over the past 25 years. The inciting fungus (*Ceratostomella ulmi*) of the Dutch elm disease is efficiently transmitted by the bark beetle, *Scolytus multistriatus.* The fungus, the bark beetle, and the disease are now found from New England to California and have resulted in the elimination from many cities of a shade tree that was once considered to be the best

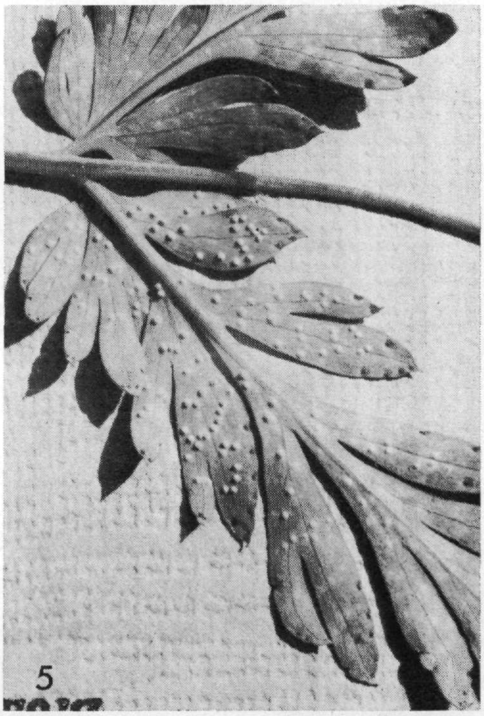


FIGURE 5. *Cerotelium dicentrae:* aecial stage on Dicentra (Dutchman's Breeches) leaves.

available. A recent report indicates 75% of the American elm population has been eliminated in 12 northeastern states.

Interest in mushroom fungi in Ohio and elsewhere in the United States on the part of non-professionals has increased greatly in recent years. Mycological clubs and organizations have increased in number and in membership. The North American Mycological Association, an example of one such organization, started in Ohio in 1960 with a small group meeting in Scioto County. With help and encouragement from several professional mycologists, it now has a membership of nearly 1000 and has annual forays with more participants than the forays of the professional Mycological Society of America.

World production of cultivated mushrooms is about 1.3 billion pounds (San Antonio 1975) and nearly 75% of this production is *Agaricus bisporus*. Second in importance is the Shiitake mushroom, *Lentinus edodes*, which is cultivated in Japan on logs of *Quercus* (oak) and several other genera. The paddy straw mushroom, *Volvariella volvacea*, is cultivated in southeast Asia on the substratum of rice straw.

Several species of truffles are widely collected for eating and include *Tuber melanosporum* and *Tuber griseum* in southern Europe and *Tirmania africana* in northern Africa (Singer 1961). The black truffle of France (*Tuber melanosporum*) is a semicultivated species. It is apparently mycorrhizal with several tree species and in France, oak plantations are established for the express purpose of obtaining crops of truffles. In Europe, one can purchase young oak (*Quercus*) and hazel (*Corylus*) trees that have roots with truffle mycelium already present, which when planted and cultivated for 8 or 10 years will yield a truffle garden. The natural distribution of the black truffle is mostly between 44° and 46° N latitude and primarily in France, Spain and Italy. The truffles are hypogeous Ascomycetes, not much to look at—but they are expensive, and reported to retail for more than $100 a pound. Annual production has been estimated at more than 3 million pounds in some earlier years but it is not likely such quantities are marketed today.

Other mushrooms cultivated, in a more limited way, include the Ear Fungus, which is a species of *Auricula;* the oyster mushroom (a species of *Pleurotus*); *Flamulina velutipes* (the winter mushroom); and a species of *Tremella*, which is one of the jelly fungi used extensively as food by the Chinese people.

The collection and use of wild mushrooms for food is extensive, especially in some European countries. Marketing of edible wild species is governed in many areas by local ordinances. On the markets of Geneva, Switzerland in 1963, 70,000 pounds of wild mushrooms were sold at an average price of $1.50 a pound. At that time some 50 species were approved for sale in the Geneva markets (Weber 1964). A number of the wild mushrooms are dried or canned, and marketed in other countries. An Associated Press news release early in 1977 reported that officials in Finland embarked on a project to exploit their naturally-occurring crop of edible mushrooms. The report suggests the collection and sale of mushrooms would make a healthy contribution to the Finnish economy. Examples of some extensively collected wild mushrooms include *Boletus edulis*, *Suillus luteus*, *Leccinum* species (fig. 6), *Morchella* species (fig. 7), *Cantharellus cibarius* (fig. 8), certain species of *Tricholoma*, *Lactarius* and *Termitomyces*. All except *Termitomyces* are found in both Europe and the United States.

> Although many wild mushrooms are food delicacies, there are many species that are toxic and no simple test is known for distinguishing them. There is an old saying, "There are old mushroom hunters, and bold mushroom hunters, but there are no old, bold mushroom hunters."

Much has been written about poisonous mushrooms and mushroom toxins, and differences of opinion and misinformation are easily found in the medical and mycological literature. In part, these differences can be explained by problems in the identification of certain species, and the continued republication of earlier reports now known to be incorrect. The taxonomy of some of these problem genera has been clarified in the last few years and much has been learned in recent years about some of the mushroom toxins. The Amanita toxins account for nearly all deaths from eating poisonous mushrooms worldwide. The number of deaths in the United States is not great but reliable records are not available.

The mushrooms reported to contain Amanita type toxins include *A. verna*, *A. virosa*, *A. bisporigera*, *A. phalloides* and certain species in the genera *Galerina* and *Conocybe*. The latter genera are not closely related to the Amanitas and fortunately are not likely to attract the attention of those collecting edible mushrooms. *Amanita bisporigera* is common in Ohio, as is *A. virosa.* Recent research indicates the toxins in *A. virosa* are not the Amanita toxins. *Amanita phalloides* is common in Europe and has been found in a few areas of the United States, but not in Ohio. The principle toxins in these mushrooms are cyclo-peptides, the amatoxins and phalloidin. The lethal dose of amatoxin for humans is approximately 0.1 mg/kg of body weight. The toxicity of phalloidin is much lower, the LD_{50} for mice being about 2 mg/kg body weight. Some basidiocarps of *A. bisporigera* may contain as much as 10 to 15 mg of the amatoxins, thus one mushroom provides enough toxin to be lethal for an adult.

The amatoxins are hepatic toxins and the extent of liver injury is indicated by a marked elevation in levels of serum glutamic-oxaloacetic and glutamic-pyruvate transaminases. Over the years there has been no satisfactory method of treating patients poisoned by the Amanita toxins—the result being a death rate of nearly 50%. Recently, treatment with thioctic acid, however, has shown promise in counteracting the effects of the amatoxins and has been widely used in Europe and more recently in this country. In Columbus last year, thioctic acid therapy was used for two persons who dined on a mixture of *Amanita bisporigera* and *A. virosa* and both patients survived.

The hallucinogenic mushrooms have received considerable attention in recent years. Mushrooms with active hallucinogenic principles are known in the genera *Conocybe, Psilocybe, Panaeolus* and *Stropharia.* Most of these species are small and are not likely to be collected by the mycophagist. Some occur in lawns and other grassy areas and could easily be involved in poisoning in young children. The toxins are indole derivatives, psilocybin and psilocin, which affect the central nervous system. Some states have passed laws prohibiting the possession of psilocybin-containing mushrooms. *Psilocybe cubensis* is a species occurring in southern Texas, Florida, Cuba, and Mexico. In a recent study, Jackson and Alexopoulos (1976) found considerable variation in the effects on consumers of this mushroom when collections from Mexico were compared with those from the Houston area. They report that *P. cubensis* occurs almost exclusively in pastures on decomposing cow dung and in early hours of the morning, cows and young people compete for the fresh basidiocarps. Cows grazing on the mushroom are not visibly affected, but young people consume it for psychedelic experiences. Any mushrooms escaping cows and people are rapidly decomposed by ants. In Texas there have been many reports of individuals suffering gastrointestinal discomfort after partaking of *P. cubensis,* and one victim reported nausea, cramps, and vomiting along with hilarity. It seems apparent that the kind and quantity of hallucinogens and/or other toxins may vary considerably in collections of the same morphologic species.

Mushrooms containing the toxins ibotenic acid and muscimol include the widely distributed *Amanita muscaria* (fig. 9) and probably *Amanita pantherina,* a species common in the Pacific northwest. Muscarine was reported at one time to be the principal toxin in *A. muscaria* and atropine was prescribed as the antidote. It is now clear that this species contains physiologically insignificant amounts of muscarine, yet the early reports found their way into many of the most recent medical and toxicology texts, which recommend treatment with atropine, which if given, complicates the problem.

Ibotenic acid and muscimol are isoxazole derivatives and have neurological effects. *Amanita muscaria* was used extensively in parts of Siberia and probably elsewhere for its psychoactive effects. The effects of this mushroom are not the typical hallucinogenic syndrome seen with LSD and psilocybin. The psychoactive compounds are not metabolized by the body and primitive peoples were aware they could get a psychedelic response by saving and drinking urine. In a report in the *Mycologia,* a woman intoxicated with *Amanita pantherina* was quoted as imagining herself in hell and concluding it was not as bad a place as some people would have us believe.

FIGURE 6. *Leccinum* sp.: one of the common edible fleshy pore fungi.
FIGURE 7. *Morchella esculenta:* an example of one of the edible morels.
FIGURE 8. *Cantharellus cibarius:* the widely collected edible chantarelle.
FIGURE 9. *Amanita muscaria:* the fly mushroom, an example of a poisonous mushroom.

Often reported as deadly, the mushrooms in this group are not highly toxic, although I am not suggesting they are edible. There are no specific antidotes for treating intoxication caused by these two Amanitas, but prognosis for recovery is excellent.

Much confusion has existed relative to the toxins in the false morels (*Gyromitra* spp.) and whether or not certain species of the genus are poisonous or edible. The situation has been clarified somewhat due to better concepts of the species, and verification of the toxin as monomethyl hydrazine or its derivative; not helvellic acid as originally thought. Monomethyl hydrazine has been used as a rocket fuel and its toxicity extensively investigated by the U.S. Air Force. It affects the central nervous system, and the mystery of why one meal of *Gyromitra* might cause no effect, while the second one would cause serious illness or even death, can now be explained. It has been found there is an extremely narrow limit between a no-effect and a lethal dose of monomethyl hydrazine. *Gyromitra esculenta* has been eaten by many individuals and this leads one to speculate how many persons have come close to the ragged edge—one more bite or meal may have been disastrous. The toxin of this mushroom is volatile and a recent report suggests this may explain the cases of intoxication reported from Europe in persons exposed to vapors during the commercial processing of *G. esculenta.* The second problem involved with *Gyromitra* is that it is not possible to accurately identify and separate the species with any mushroom guide available in this country. In fact, one is likely to misidentify them. I have studied the genus for a number of years and have become aware of problems of identifying the species, especially if one makes the mistake of referring to more than one book. Gross morphology cannot be relied on to separate the species—and this is, of course, what most mushroom collectors use. Characteristics of the ascospores must be determined and the ascospores must be mature. Spore size, shape and markings change with age, and this has been another source of error in the literature. Spores may appear to be mature when they are not. We owe much to McKnight (1971; 1973) for clarifying the taxonomy of this genus in the United States. Considering all the problems, toxicologic and taxonomic, one is well advised to avoid eating false morels in spite of the many mushroom books reporting some species as edible.

The muscarine-containing species of mushrooms include several species of *Inocybe* and *Clitocybe.* Some of these species occur in lawns or under trees near homes and therefore are likely to be eaten by young children. As much as 1% muscarine on a dry weight basis is found in some species. Muscarine stimulates the parasympathetic nervous system. The symptoms include increased sweating, salivation, lachrimation, reduced blood pressure, blurred vision, asthmatic breathing, nausea and severe vomiting. Muscarine is not a central nervous system toxin as sometimes reported. Atropine is a specific antidote for this type of poison. Determination of species of *Clitocybe* and *Inocybe* is not easy and the genera should be avoided by the mycophagist.

Consumption of alcohol after a meal of *Coprinus atramentarius,* one of the inky cap mushrooms, has been repeatedly reported to result in symptoms resembling the antabuse syndrome. There is a substance in this mushroom which interferes with the normal activity of enzymes metabolizing ethanol, which has recently been identified as a glutamine complex and given the common name *coprine.*

A number of other mushrooms have been identified as causing intestinal up-

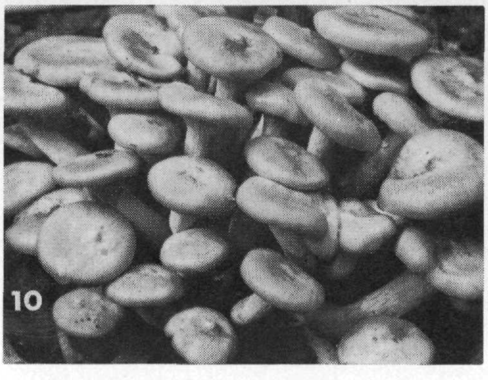


FIGURE 10. *Clitocybe illudens:* the Jack-O-Lantern mushroom. It is bright orange and mildly poisonous.

sets—mild to severe. Symptoms usually terminate within 3–4 hrs. and recovery is complete in a day or two. Although their toxins have not been identified, examples include *Lepiota morgani*, with a greenish spore print, the beautiful *Clitocybe illudens* (fig. 10), *Russula emetica*, and *Cantharellus floccosus*.

In conclusion, I wish to quote M. C. Cooke, a 19th century British mycologist, who also believed the fungi to be fascinating organisms worthy of more understanding and study for either their harmful or beneficial activities. In his book on British Fungi, published in 1862, he writes,

> "Let me assure the student that, all times, seasons, and localities will afford him some species for examination; and whether he has felt interested in them before, or now for the first time, adopts these interesting plants as objects worthy of his special regard, I would commend them to his patient and persevering attention, in the assurance that this pursuit will lead 'from joy to joy'."

LITERATURE CITED

Alexopoulos, C. J. 1962 Introductory Mycology. 2nd ed. John Wiley and Sons.

Caporael, Linnda R. 1976 Ergotism: The Satan loosed in Salem. Science 192: 21–26.

Ciegler, A. 1975 Mycotoxins: occurrence, chemistry, biological activity. Lloydia 38: 21–35.

Cooke, W. B. 1973 Some backgrounds for an Ohio Mycobiota. Ohio J. Sci. 73: 83–88.

Cooke, W. B. 1973a Back-yard fungi. Ohio J. Sci. 73: 88–96.

Ellett, C. W. 1957 The parasitic fungi of Ohio plants. Ohio J. Sci. 57: 236–242.

——— 1956 Curvularia blight of *Ophioglossum*. Plant Disease Reptr. 40: 756.

Holm, L. 1969 An uredinological approach to some problems in angiosperm taxonomy. Nytt Mag. Bot. 16: 147–150.

Huang, L. H. and J. A. Schmitt 1975 Soil microfungi of central and southern Ohio. Mycotaxon 3: 55–80.

Jackson, R. E. and C. J. Alexopoulos 1976 *Psilocybe cubensis* (Agaricales): A comparison of Mexican and Texas types. Southwestern Naturalist 21: 227–233.

Large, E. C. 1940 The advance of the fungi. Henry Holt and Co., New York. 488 p.

McKnight, K. H. 1971 On two species of false morels (*Gyromitra*) in Utah. The Great Basin Naturalist 31: 35–47.

——— 1973 Two misunderstood species of *Gyromitra* (false morels) in North America. Michigan Bot. 12: 147–162.

San Antonio, J. P. 1975 Commercial and small scale cultivation of the mushroom, *Agaricus bisporus* (Lange) Sing. Hort. Sci. 10: 451–458.

Singer, R. 1961. Mushrooms and truffles. Interscience Publishers, Inc. New York. 272 p.

Weber, C. 1964 The popularity of edible mushrooms in Geneva. Econ. Botany. 254–255.

Williams, L. E. and A. F. Schmitthenner 1956 Genera of fungi in Ohio soils. Res. Circular No. 39. Ohio Agri. Exp. Station. 7 p.